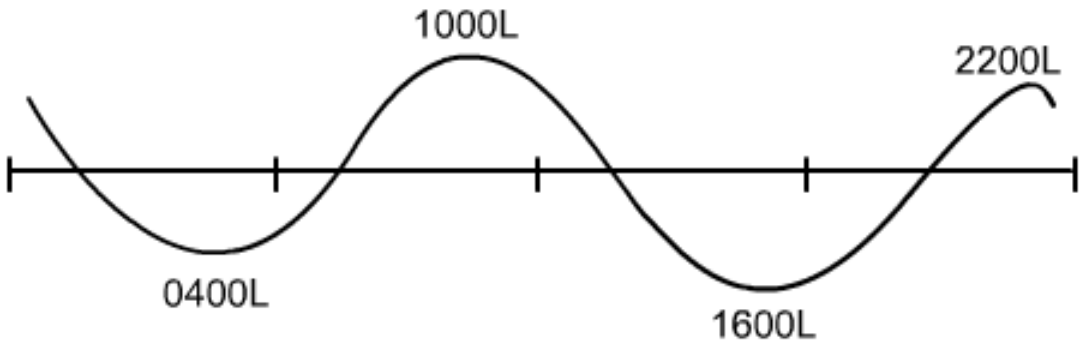
Atmospheric Dynamics III

5e. Determine the local modification to large-scale circulation patterns.

Diurnal Effects

- Pressure and Height Fluctuations
  - Daily Pressure Curve
    - Diurnal oscillation in barometric pressure
      - Daily maximum usually occurs after max cooling and 12 hours later
      - Daily minimum usually occurs after max heating and 12 hours later

DIURNAL PRESSURE CHANGES



Diurnal Effects

- Magnitude of oscillation depends on geographical location
  - Areas with large diurnal temperature change will also have large diurnal pressure change
  - Desert regions can have diurnal variations of nearly 5 mb but in general, changes do not exceed 2 mb

Diurnal Effects

- Oscillation is due to uneven heating of earth and the gravitational attraction of the Moon

– Terminology

- Hot Chart - Chart times during or just after max heating (0000 UTC in the US)
- Cold Chart - Chart time during or just after max cooling (1200 UTC in the US)

Diurnal Effects

- Significance of Surface Pressure Changes
  - Consider whether a change is due to dynamics or diurnal effects
  - Diurnal changes tell nothing about dynamic changes

Diurnal Effects

- 12-Hour Central Pressure Changes
  - Determine whether the system is changing intensity or responding to diurnal effects
  - Diurnal changes versus dynamic changes
    - » Cold chart

1. Two-millibar or less pressure rise is diurnal
2. More than 2 mb or any fall is dynamic

Diurnal Effects

- »Hot chart
  1. Two-millibar or less pressure fall is diurnal
  2. More than 2 mb or any rise is dynamic
- – Heat lows will typically have a larger diurnal change in central pressure, possibly approaching 5 mb

Diurnal Effects

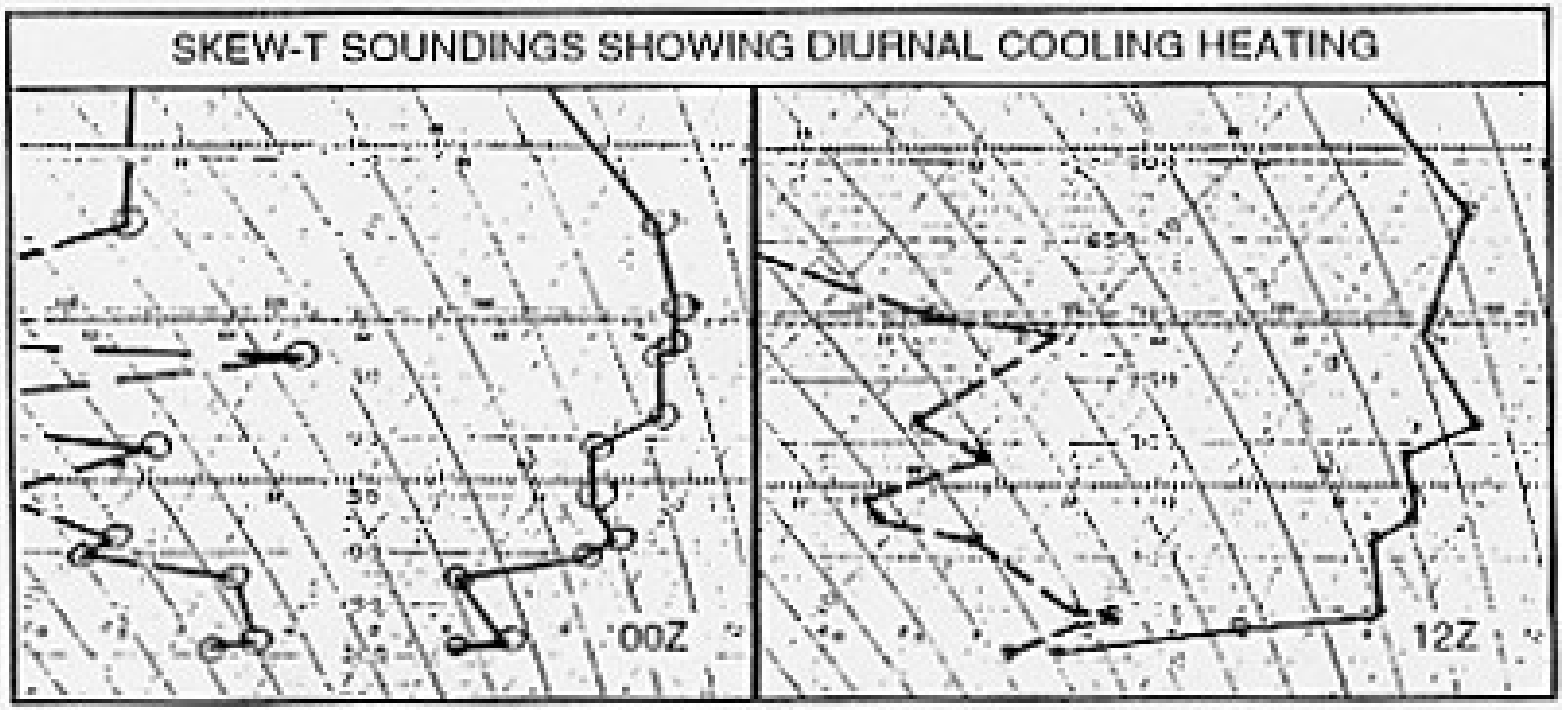
- 3-Hour Pressure Changes at Stations (APP's)
  - Again, consider whether pressure change is diurnal or dynamic
  - Diurnal changes versus dynamic changes
    - » Cold chart
      1. 1.5 mb or less pressure rise is diurnal
      2. More than 1.5 mb rise or any fall is dynamic
    - » Hot chart
      1. 1.5 mb or less pressure fall is diurnal
      2. More than 1.5-mb fall or any rise is dynamic

Diurnal Effects

- Significance of Upper-Level Height Changes
  - Diurnal effects as well as dynamic forcing influence upper-level height changes
  - Diurnal changes generally do not exceed 20 meters usually at the 850 and 700-mb levels

Diurnal Effects

- Stability
  - Hot Chart - Surface is warmest and upper-levels warm slower, thus unstable
  - Cold Chart - Surface is coldest and upper-levels cool slower, thus stable


SKEW-T SOUNDINGS SHOWING DIURNAL COOLING HEATING
00Z
12Z
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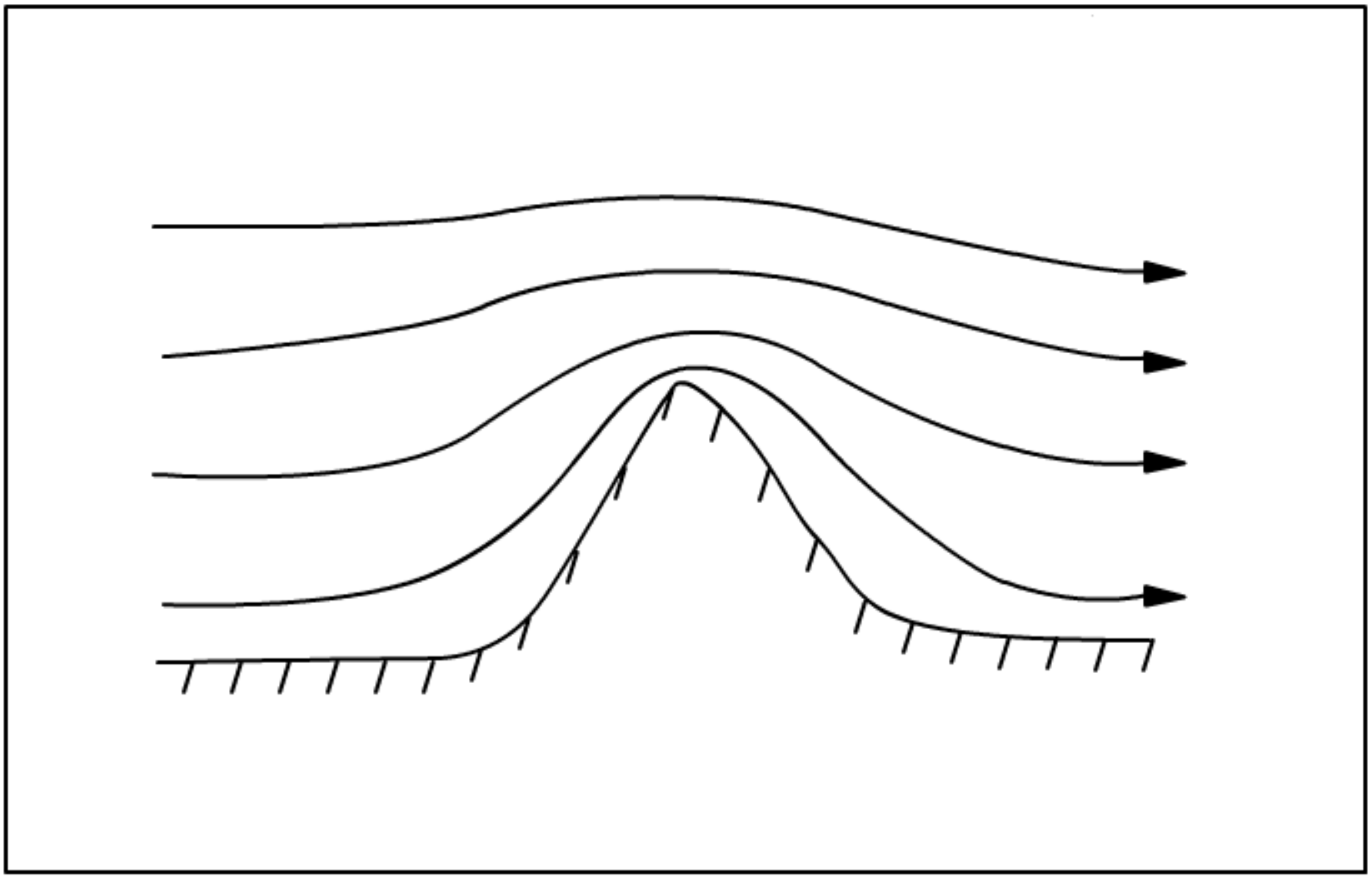
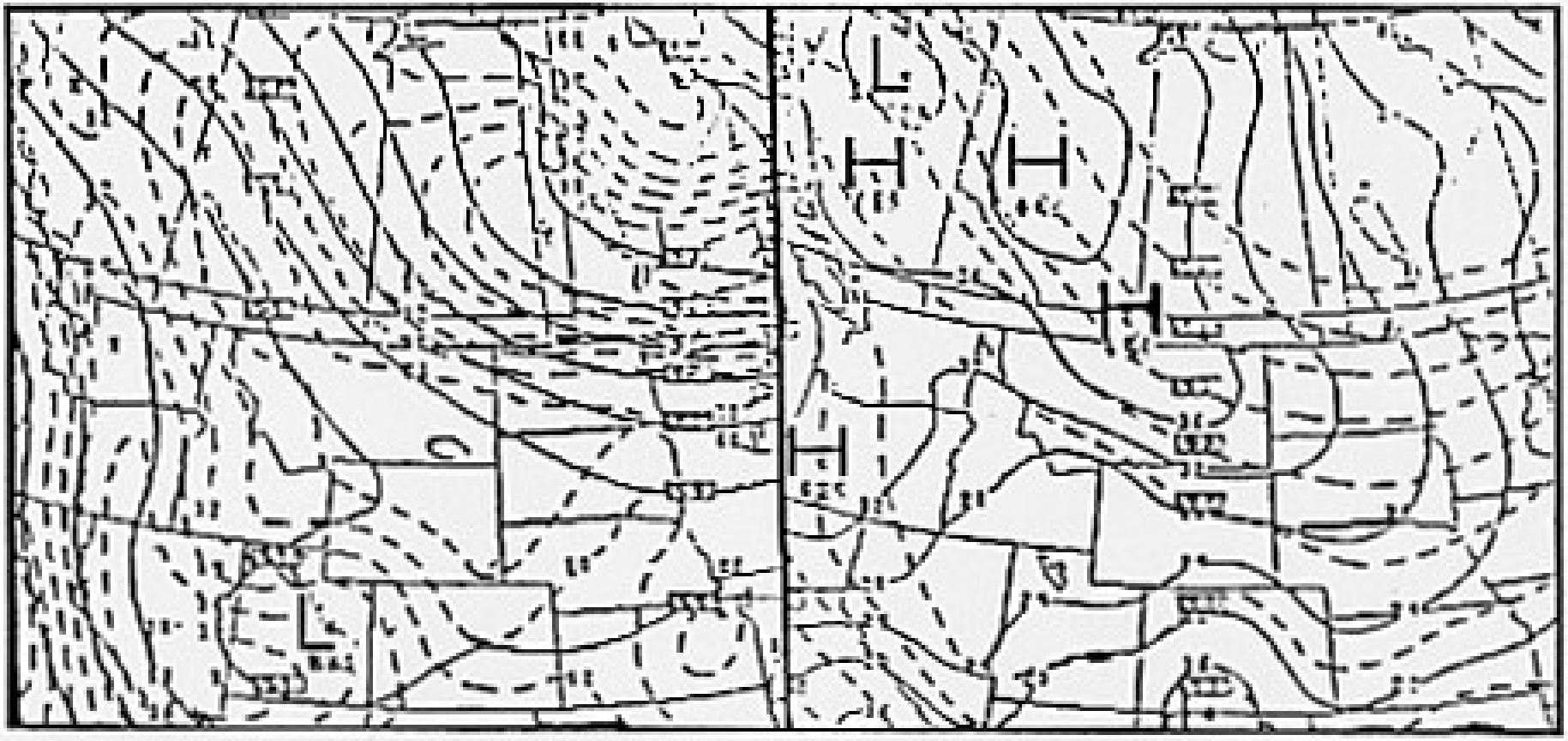
Terrain Induced Local Effects

- Upslope
  - Gradient induced wind is forced up a mountain barrier
    - Air is cooled adiabatically
    - Cloudiness/precipitation results if moisture available



Terrain Induced Local Effects

- Two scenarios
  - Cold cP high settles into northern Plains causing easterly flow to glide up sloping terrain
  - Upper trough along west coast U S cuts off causing deep southeasterly flow of moist Gulf air to glide upslope



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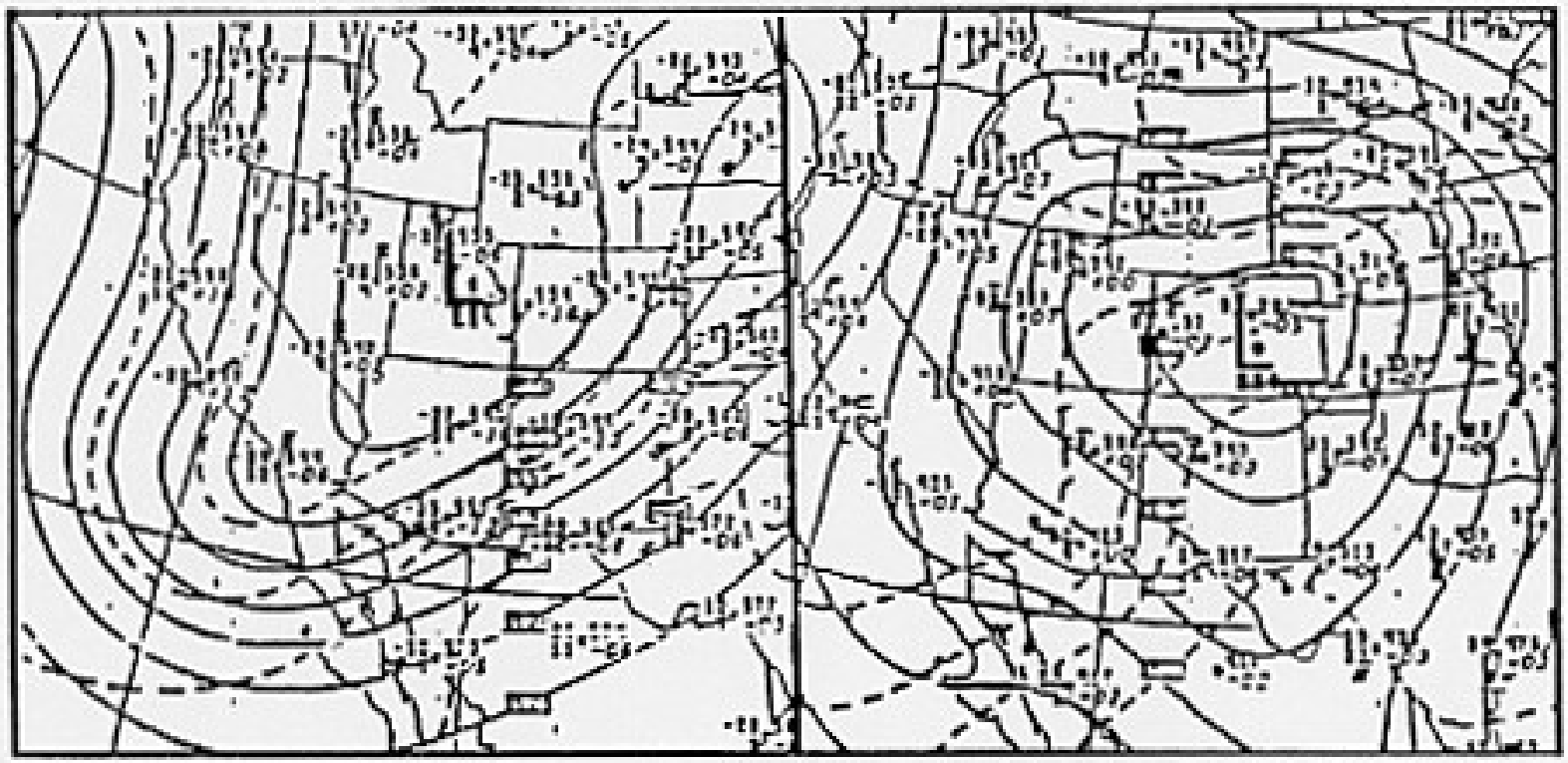

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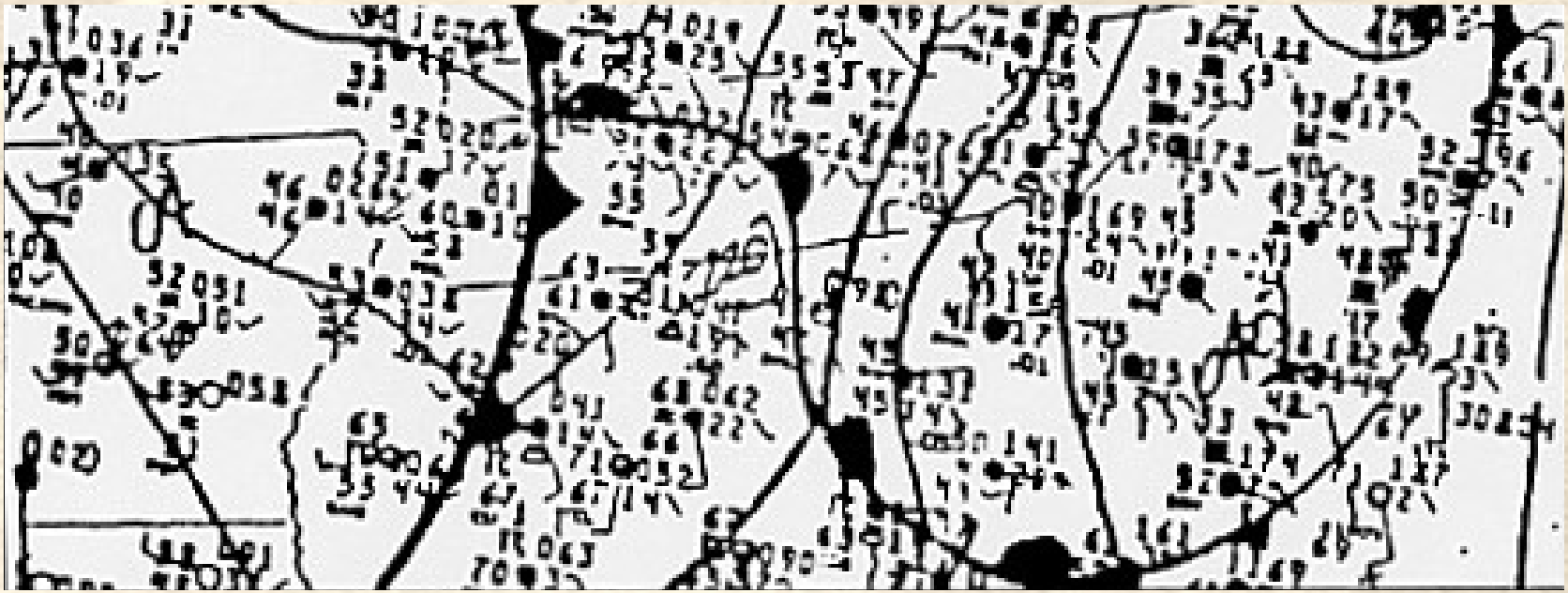
Terrain Induced Local Effects

- Cold Air Damming
  - This occurs when cold air flows southward along eastern slopes of a mountain range and air is too dense to lift up over mountains
  - The cold air mass is shallow
  - One of best indicators is forming of surface high-pressure ridge over cold air
  - Winds in shallow cold air are mostly ageostrophic and tend to be northerly, no matter what the gradient



Cold Air Dammed against the Appalachian Mount

Terrain Induced Local Effects

- Significant along slopes of both Rockies and Appalachians
  - In the Appalachians
    - The shallow cold air is dammed along the mountains as warm air tries to flow into region
    - Result is intense overrunning of shallow cold air and heavy precipitation
  - In Rockies
    - Shallow cold air flows into central plains
    - Unless a very strong easterly flow prevails, cold air does not spill westward over mountains
    - Southwesterly flow aloft sets up an ideal overrunning pattern

Terrain Induced Local Effects

- Downslope Winds
  - Downslope winds are a gradient-induced flow down a mountain
  - Types of downslope winds
    - Warm downslope winds
      - A generic term applied to warm downslope winds is Foehn but different areas have their own names; ie Chinook in Rockies
      - Foehn winds are associated with warm, windy, dry weather

Terrain Induced Local Effects

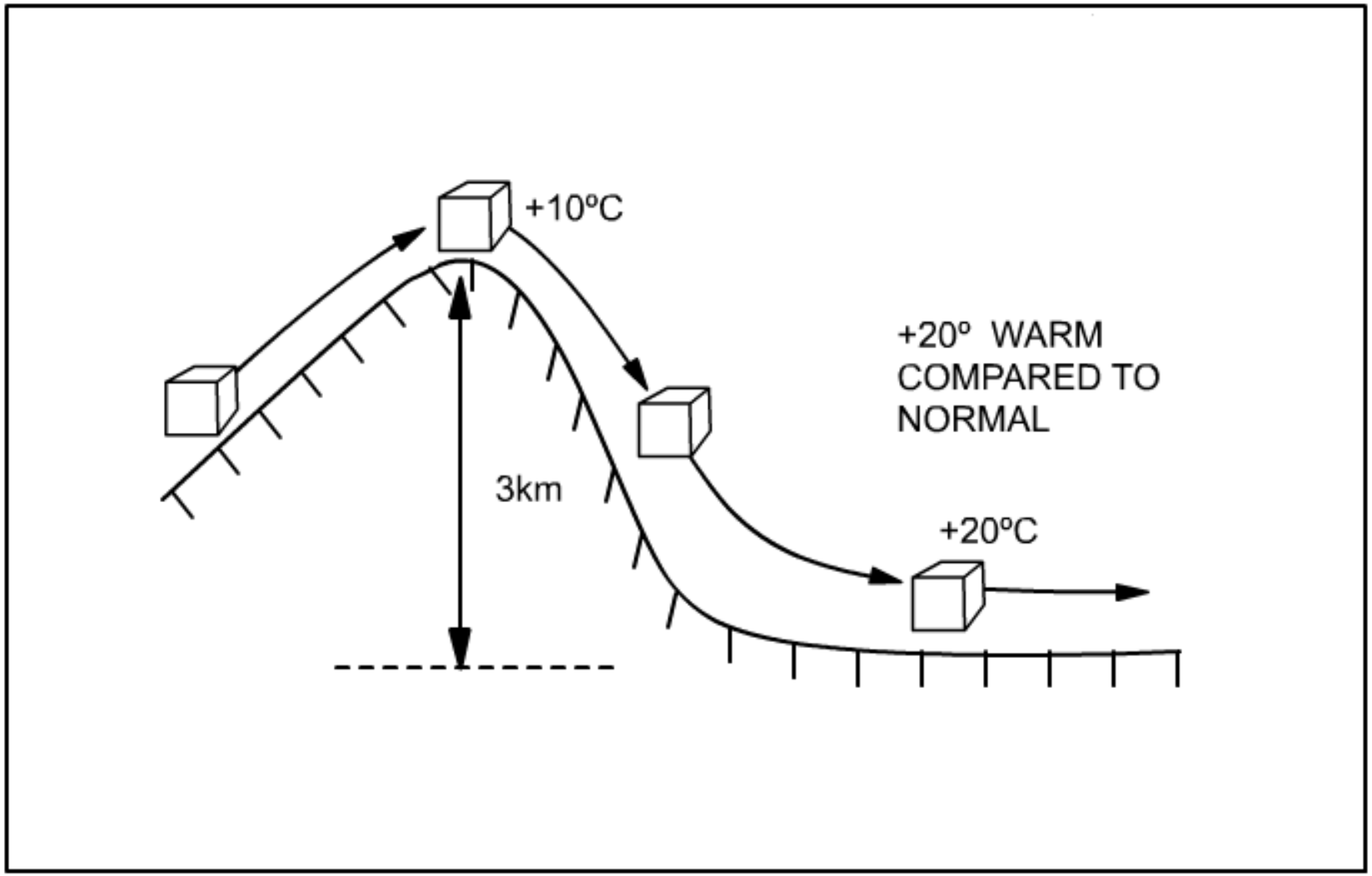
- Same synoptic situation that forms Foehn, forms a lee-side trough and are usually seen together

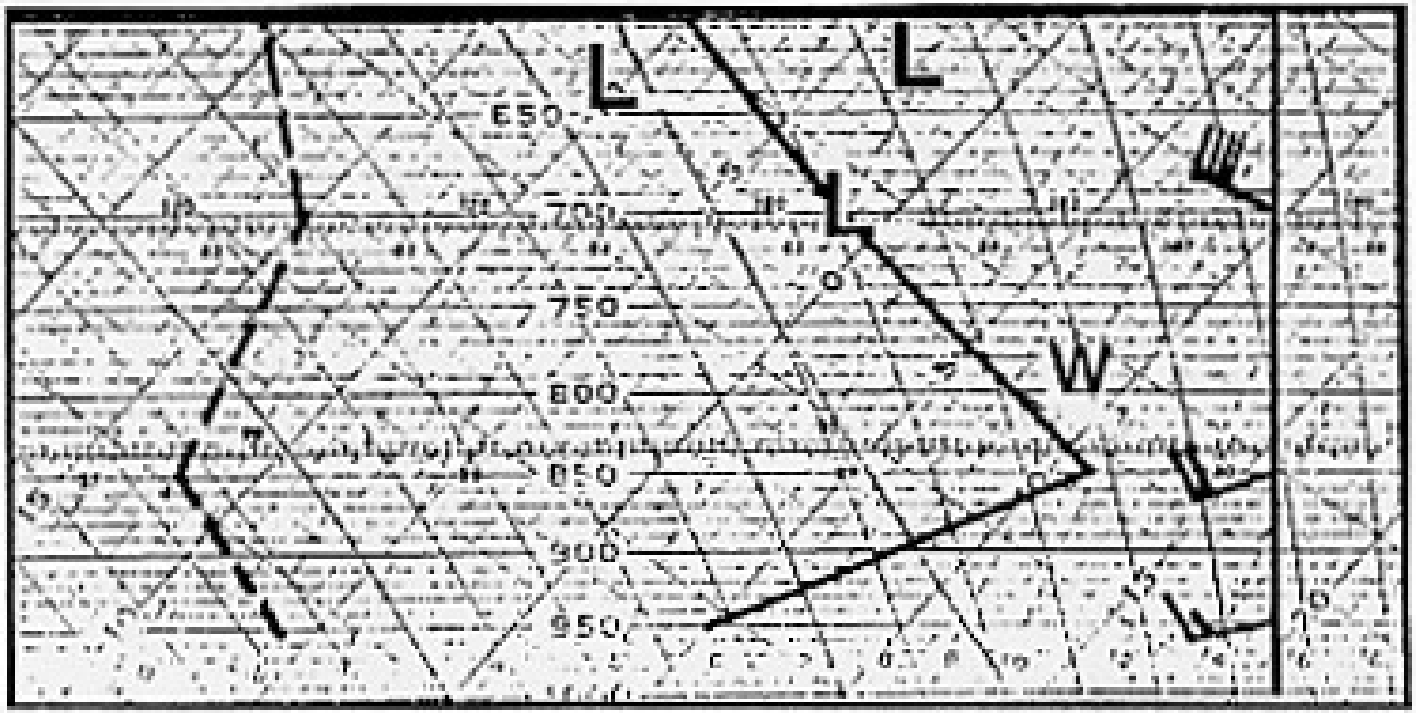
Chinook

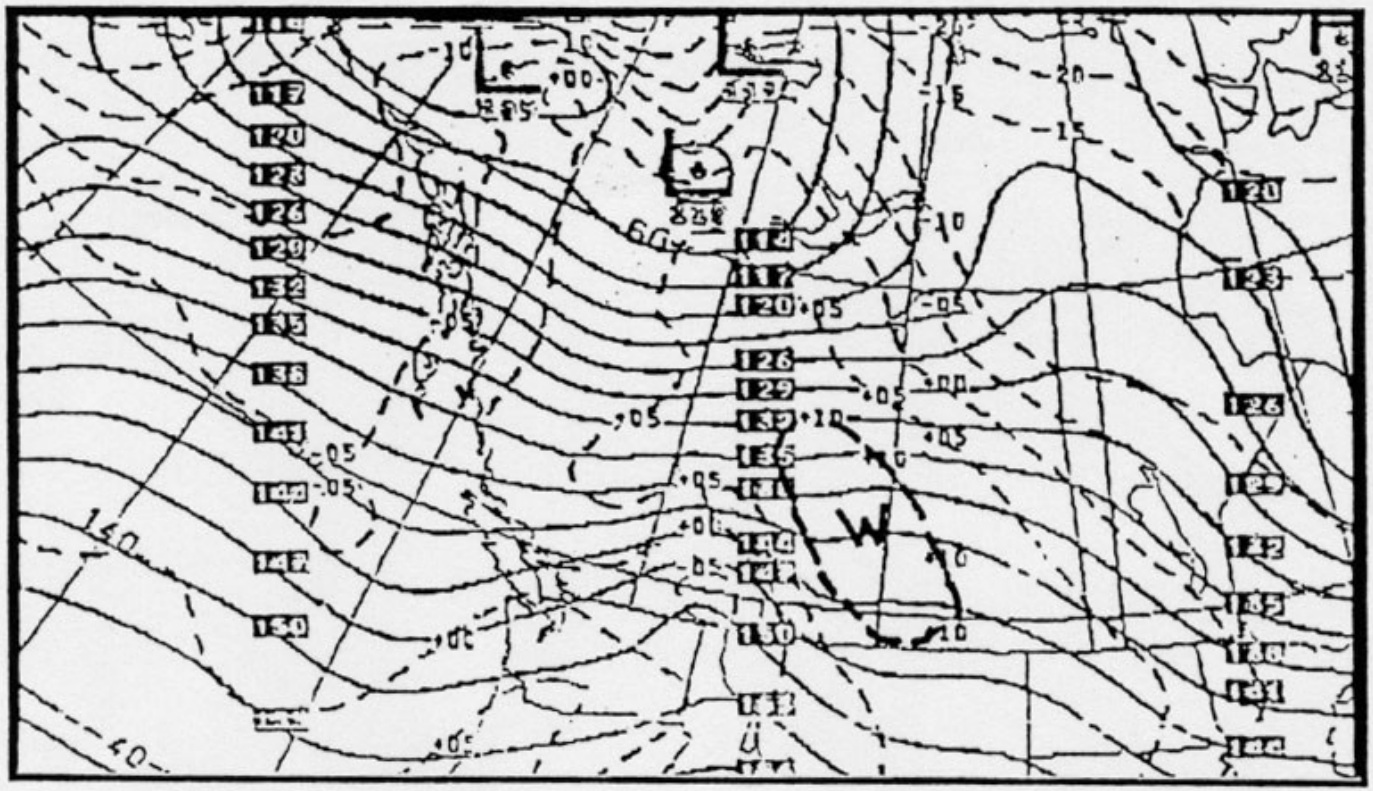
Skew-T during Chinook

850-mb

Chart During a Chinook


+10ºC
+20º WARM
COMPARED TO
NORMAL
3km
+20ºC


L
L
W
W
650
700
750
800
850
900
950
AARIW071005-9404-191



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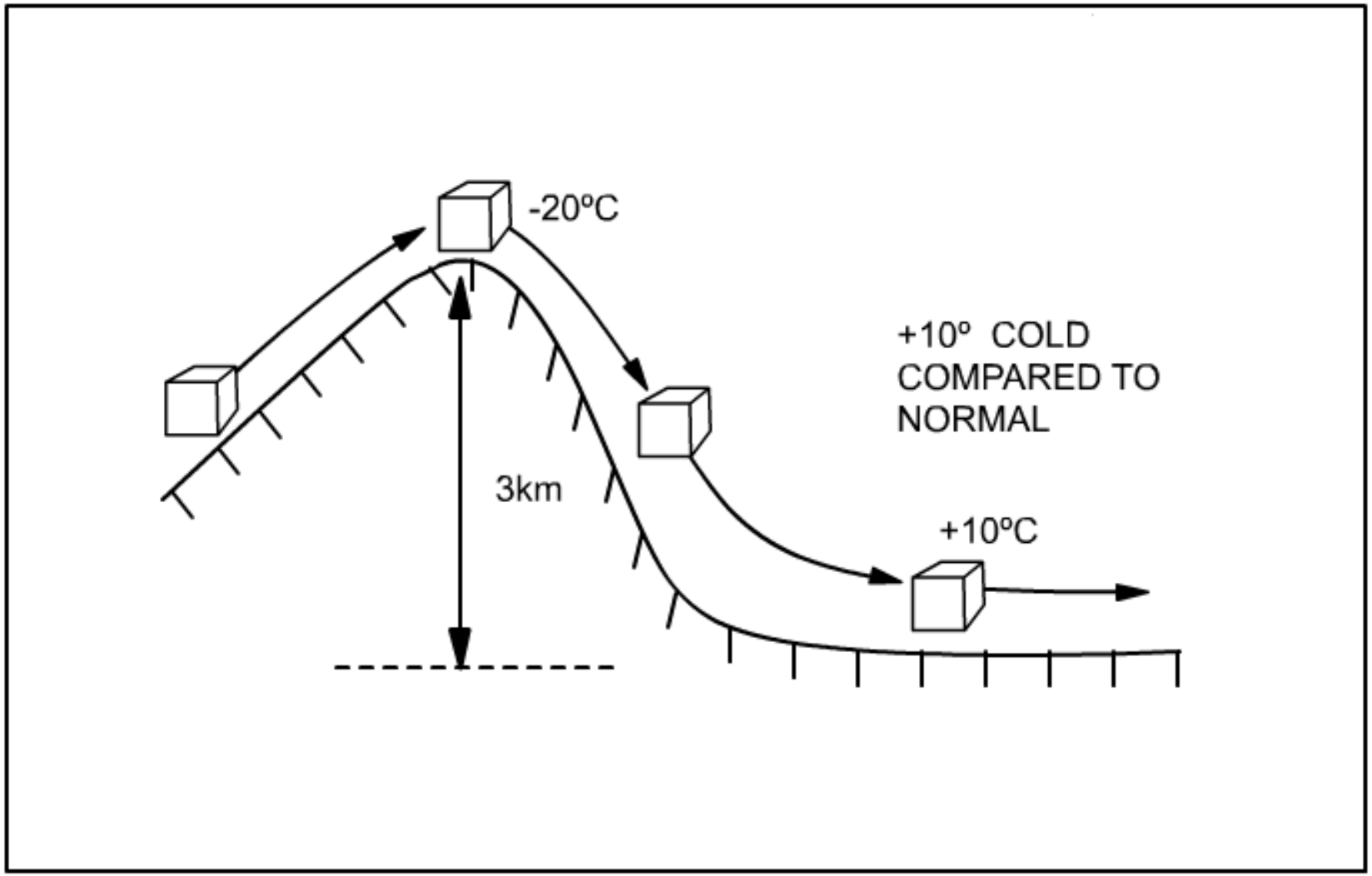
Terrain Induced Local Effects

- Cold downslope winds
  - A generic term applied to cold downslope winds is Bora
  - Boras are associated with windy, cold weather


-20ºC
+10º COLD
COMPARED TO
NORMAL
3km
+10ºC

Terrain Induced Local Effects

- Both undergo adiabatic warming and difference is how they compare with climatological norms
  - Chinook, which blows into eastern Colorado replacing cold cP air, will be relatively warm
  - Bora, which originates, as cold cP air, even after warming adiabatically, will still be relatively cold compared to mild air, which is norm for a coastal plain

Terrain Induced Local Effects

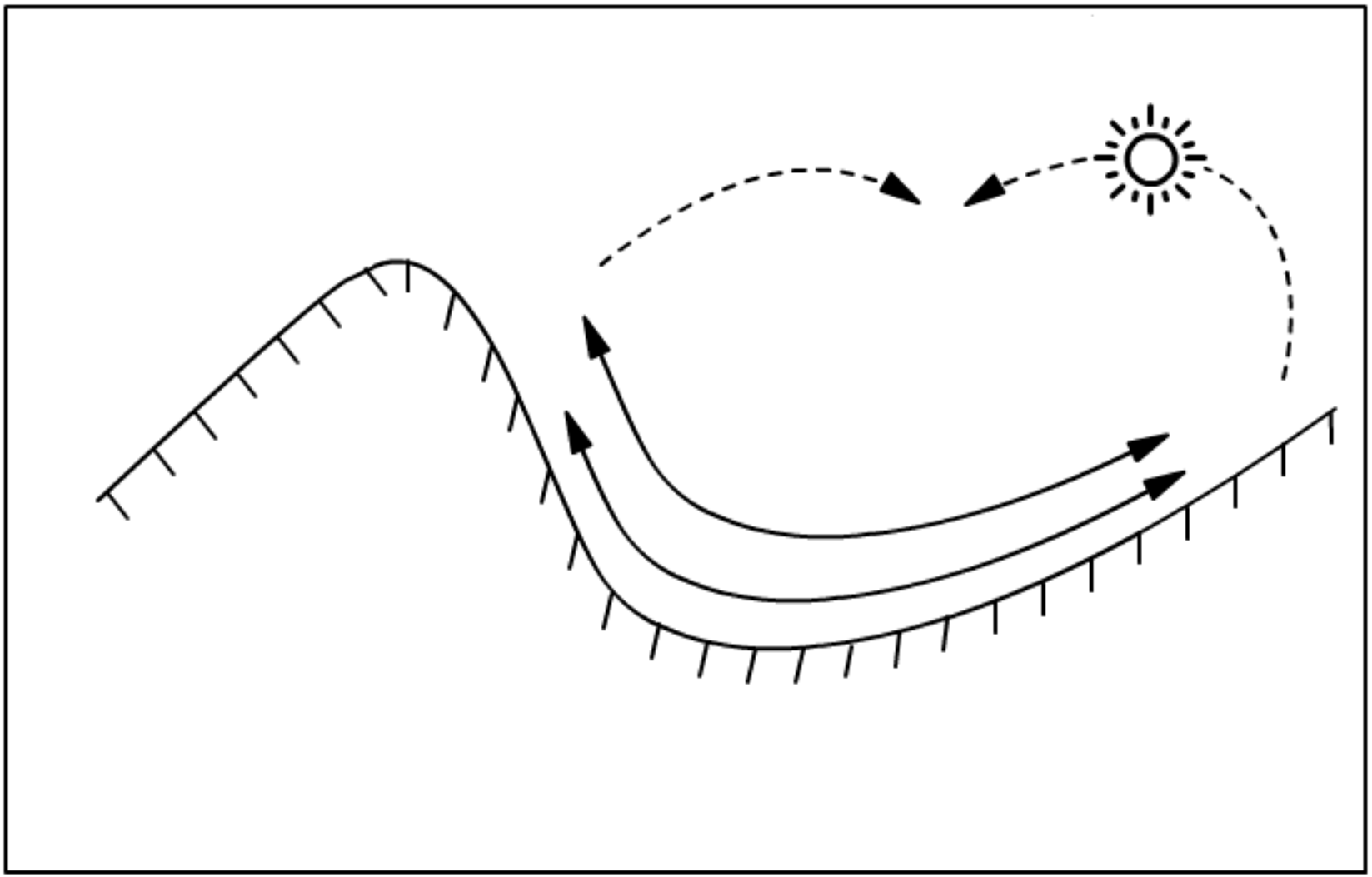
- Thermally Induced Circulations
  - Local heating and cooling drives thermal circulations
  - These are easily detected if synoptic scale pressure pattern is weak (no gradient flow)

Terrain Induced Local Effects

- Types of thermal circulations
  - Valley Breeze (Ahrens, 1985)
    - Locally induced circulation
    - Wind blows from valley to mountain
    - Daytime phenomena

Terrain Induced Local Effects

- Develops in morning and reaches peak in aft ernoon
- Cause
  - » Daytime heating occurs, air along valley walls warms
  - » Warmer, less dense air rises up the valley walls

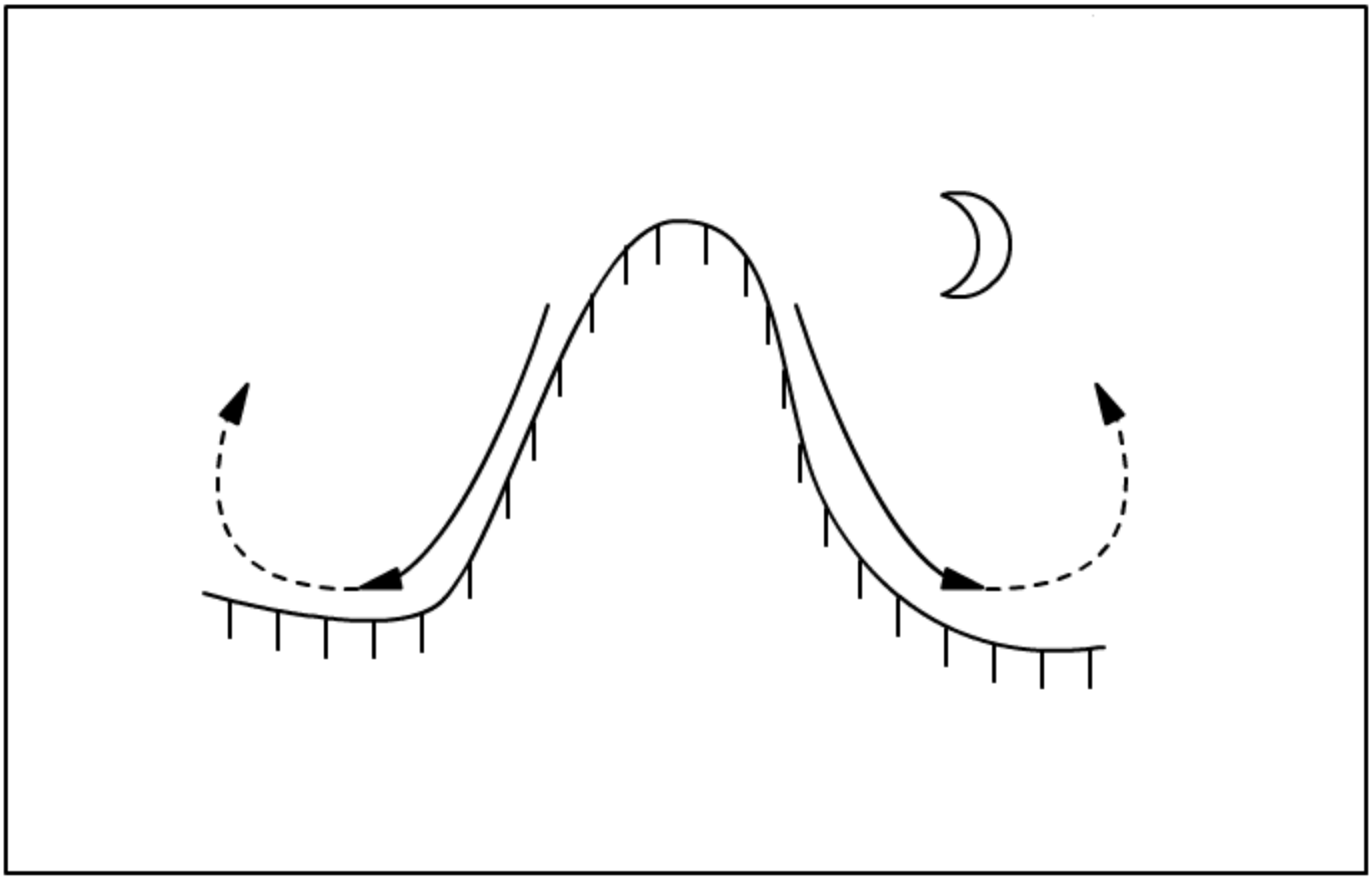


Terrain Induced Local Effects

- Mountain Breeze (Ahrens, 1985)
  - Locally induced circulation
  - Wind blows from mountain to valley
  - Nocturnal (nighttime) phenomena

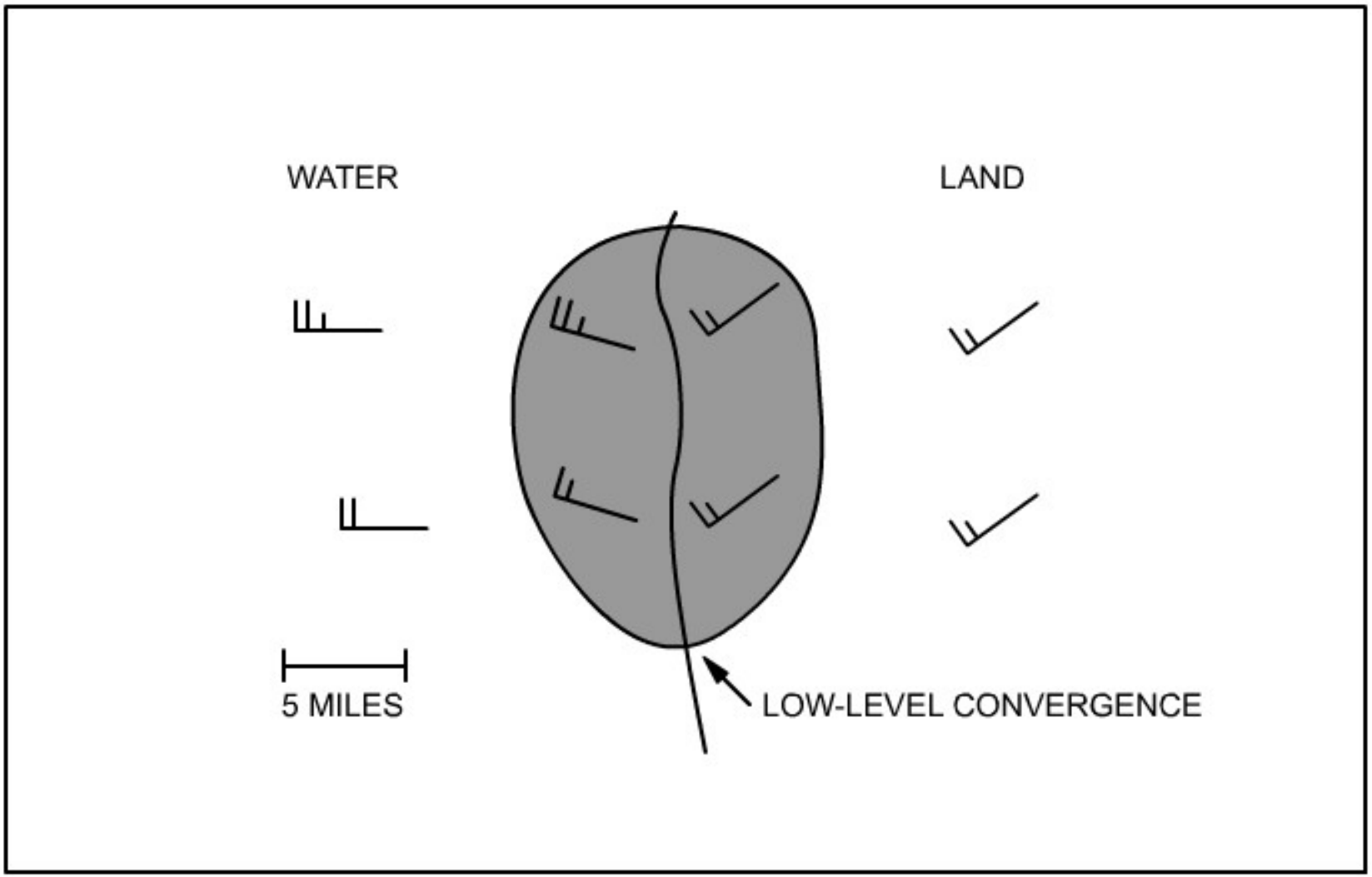
Terrain Induced Local Effects

- Develops after sunset, and reaches peak arou nd sunrise
- Causes
  - » Nighttime cooling occurs, air along valley walls cools
  - » Cooler, more dense air descends into the valley



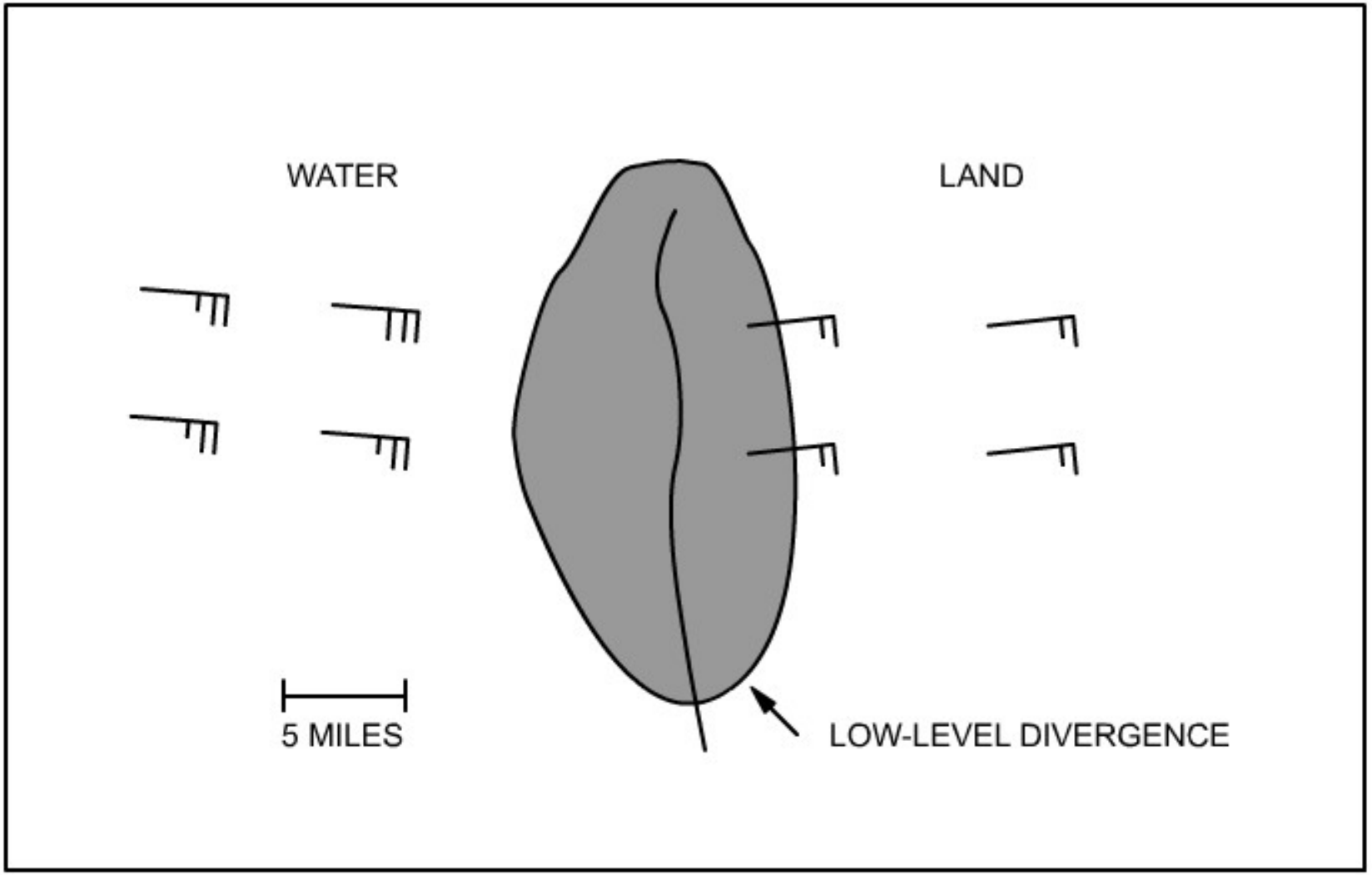
Land/Water Interactions

- Synoptic Scale (gradient driven)
  - Onshore flow - synoptic scale pressure gradient supports flow from water to land
    - Air flows onshore and friction increases, causing wind to slow and back
    - Low-level convergence occurs along coastline


WATER
LAND
5 MILES
LOW-LEVEL CONVERGENCE

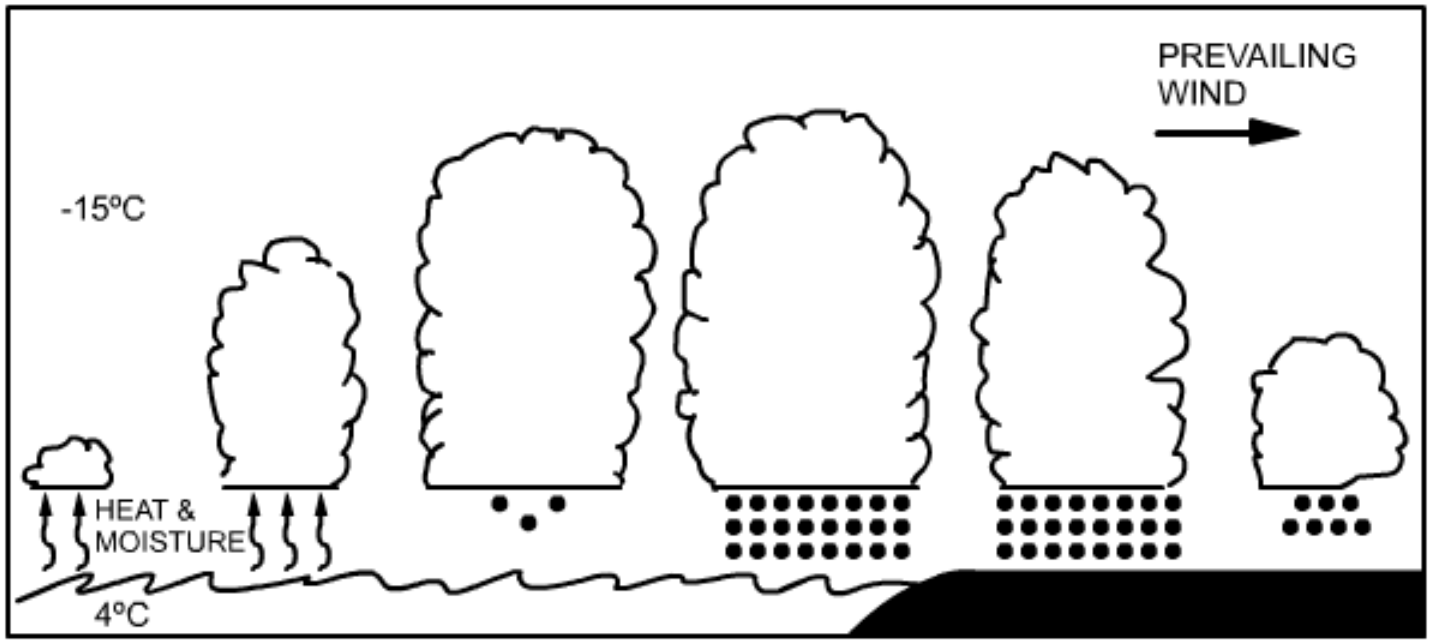
Land/Water Interactions

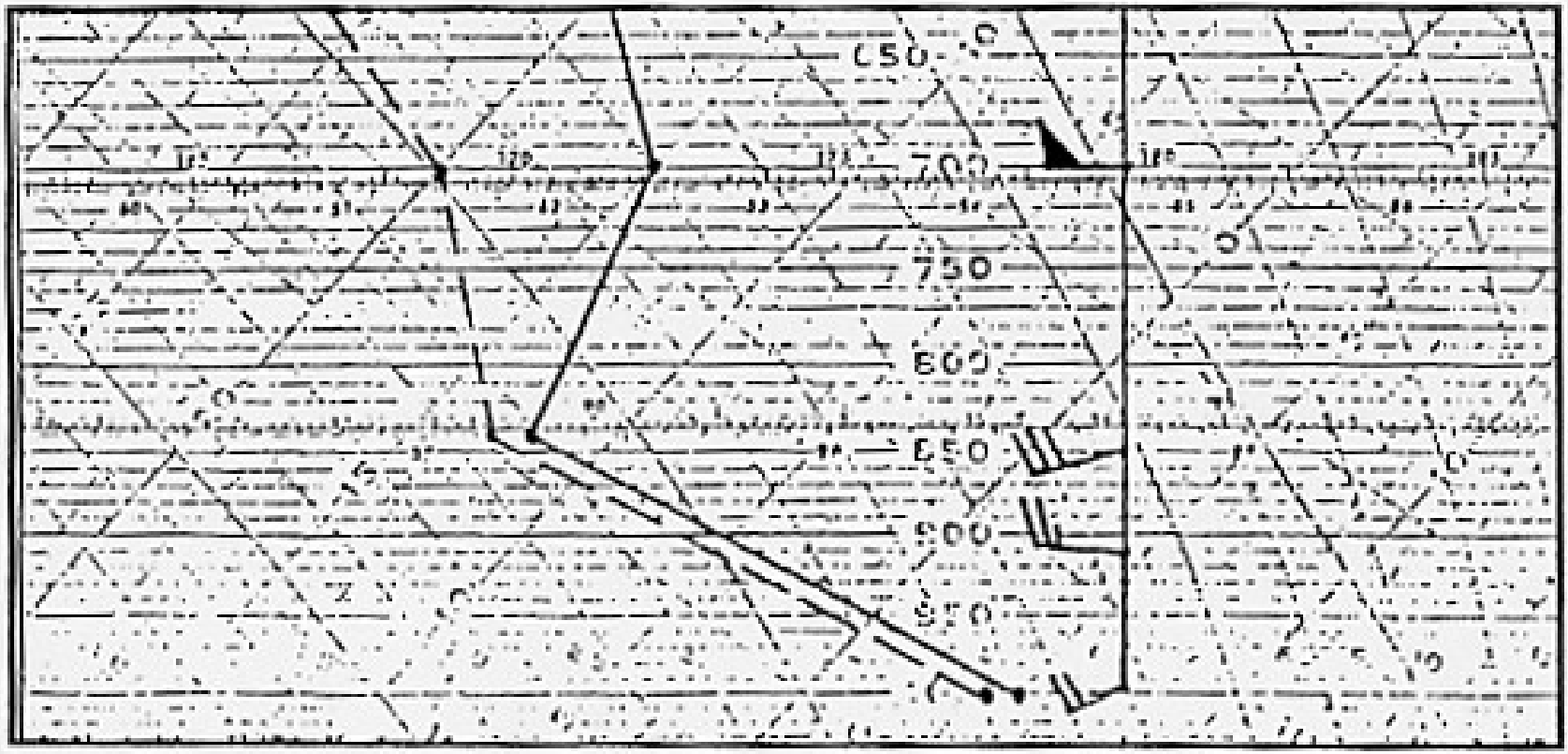
- Offshore flow - synoptic scale pressure gradient supports flow from land to water
  - Air flows offshore, friction decreases and causes wind to speed up and veer
  - Low-level divergence occurs along coastline


WATER
LAND
5 MILES
LOW-LEVEL DIVERGENCE

Land/Water Interactions

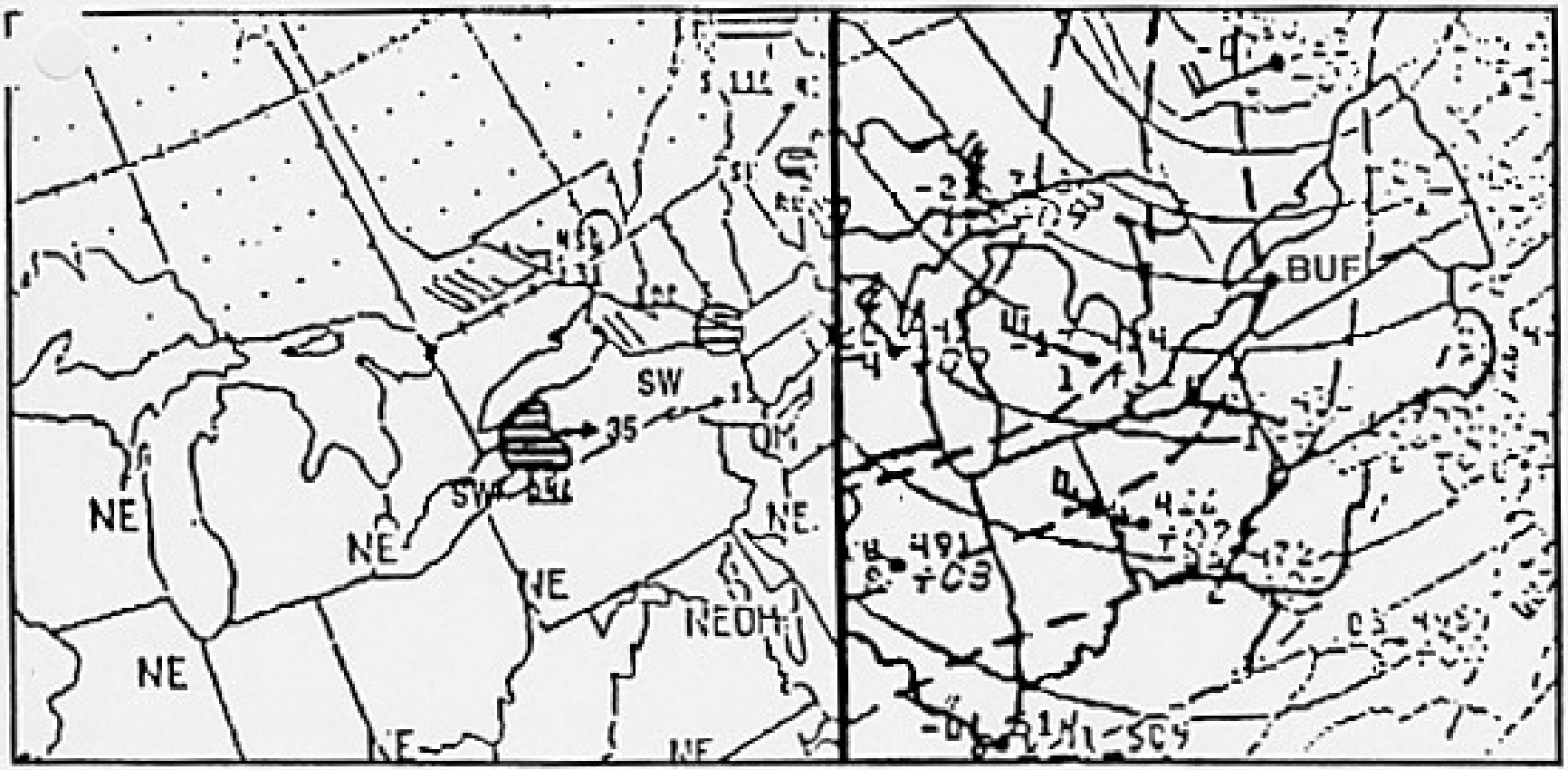
- Lake Effect Snow Squalls
  - Organized line of snow showers forming on leeside of large, unfrozen bodies of water in cold season
  - Forms over lake
  - Moves across lee side
  - Significant snows generally confined to within 25 miles of lake; light snow may extend further inland


PREVAILING
WIND
-15ºC
HEAT &
MOISTURE
4ºC


650
700
750
800
850
900
950
AAR1W071005-9404-198

Land/Water Interactions

- Caused by upward transfer of heat/moisture to cold air above
- The larger the temperature difference between lake/air, the more intense snow squalls
- Requires 15 oC temperature difference between water and 850-mb temperatures for significant snow squalls to develop
- Max snowfall normally occurs on east/south shores
- Occasionally associated with development of small low over warm lake


SW
35
NE
NE
NE
NE
NE
NE
NE
NE
NEOH
BUF
AAR1W071005-9404-199

Mesoscale (no gradient)

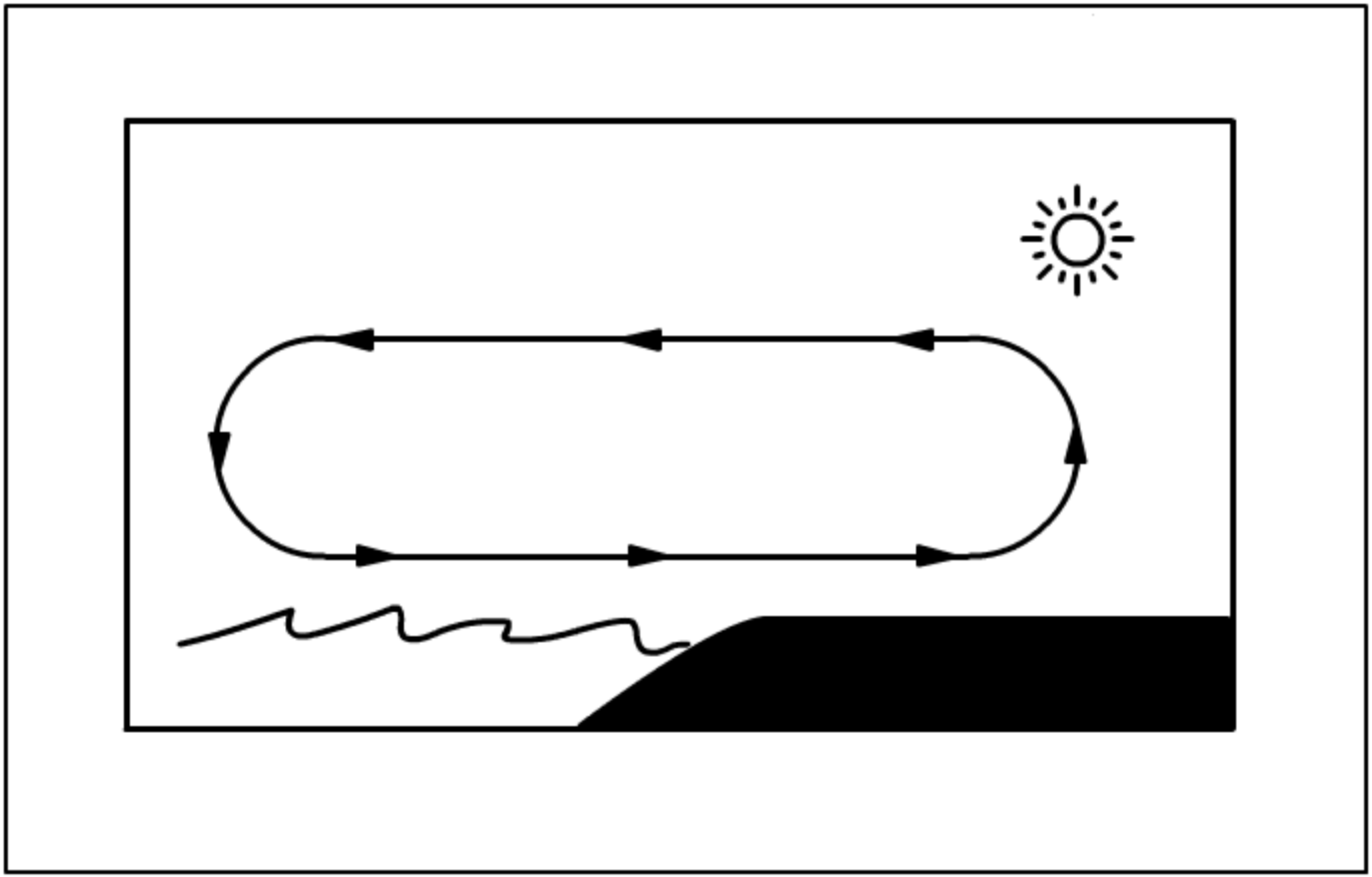
- Sea (or Lake) Breeze
  - Locally induced circulation
  - Wind blows from water to land
  - Daytime phenomena
  - Develops late morning, reaching peak in late afternoon (max heating)

Mesoscale

- Air flows from sea/lake to the land
- May extend up to 30 miles inland
- Vertical extent is from 2,000 to 4,000 ft AGL – average being 3,300 ft
- Highly dependent on the atmospheric stability and the intensity of the surface heating

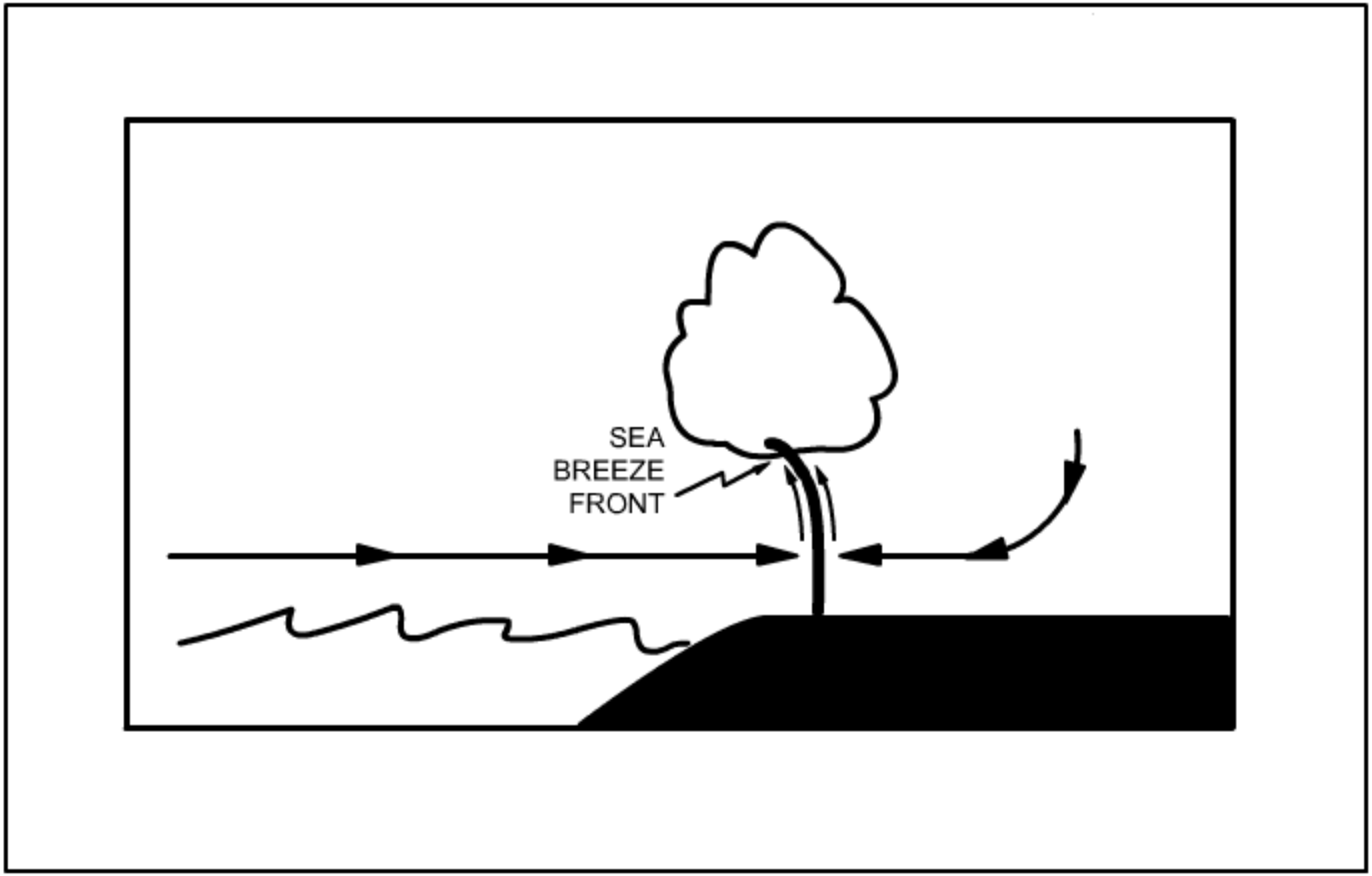
Mesoscale

- Considered the strongest diurnal wind in the tropics, speeds between 10-20 knots have been observed
  - Land heats faster than water during day
  - Warm air rises
  - Cooler air moves inland to replace rising air



Mesoscale

- Sea (or Lake) Breeze Front
  - Strong low-level convergence develops along boundary between cool air advancing inland and warmer air over land
  - Boundary acts as small scale cold front
  - Thunderstorms may develop along boundary due to intense convergence along front

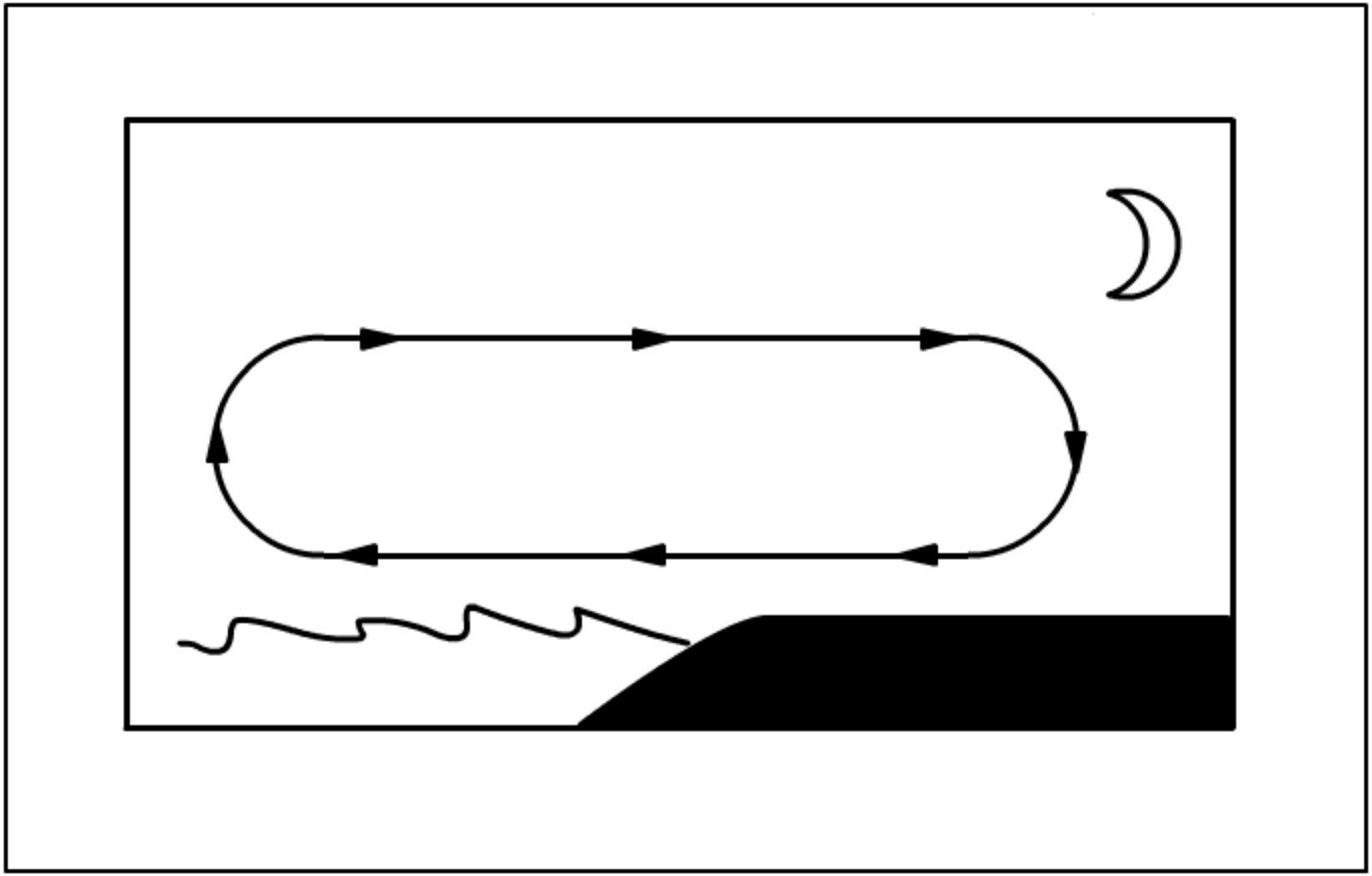

SEA
BREEZE
FRONT

Mesoscale

- Land Breeze
  - Locally induced circulation
  - Winds flow from land to water
  - Generally extends only 5 to 6 miles out to sea
  - Nocturnal (nighttime) event
  - Winds are generally less than 10 knots

Mesoscale

- Develops after sunset, reaches peak near sunrise
  - Formation
  - Land cools faster than water during night
  - Warm air rises
  - Cooler air moves offshore to replace rising air



Mesoscale

- Lee-side trough
  - Caused primarily by adiabatic heating on the lee-side of a mountain chain
  - Generally cloud free due to a lack of moisture

Mesoscale

- Atmospheric eddy currents
  - A circulation produced on the lee-side of a barrier
  - Intensity decreases downstream from the barrier
  - Considered to be an area of turbulence due to strong directional and speed shear
    - » Land heats faster than water during day
    - » Warm air rises
    - » Cooler air moves inland to replace rising air

Low-Level Jet (LLJ)

- The low-level jet is a band of strong (30 knots or greater) supergeostrophic southerly winds which develops above the top of the boundary layer (about 900 mb)

Low-Level Jet (LLJ)

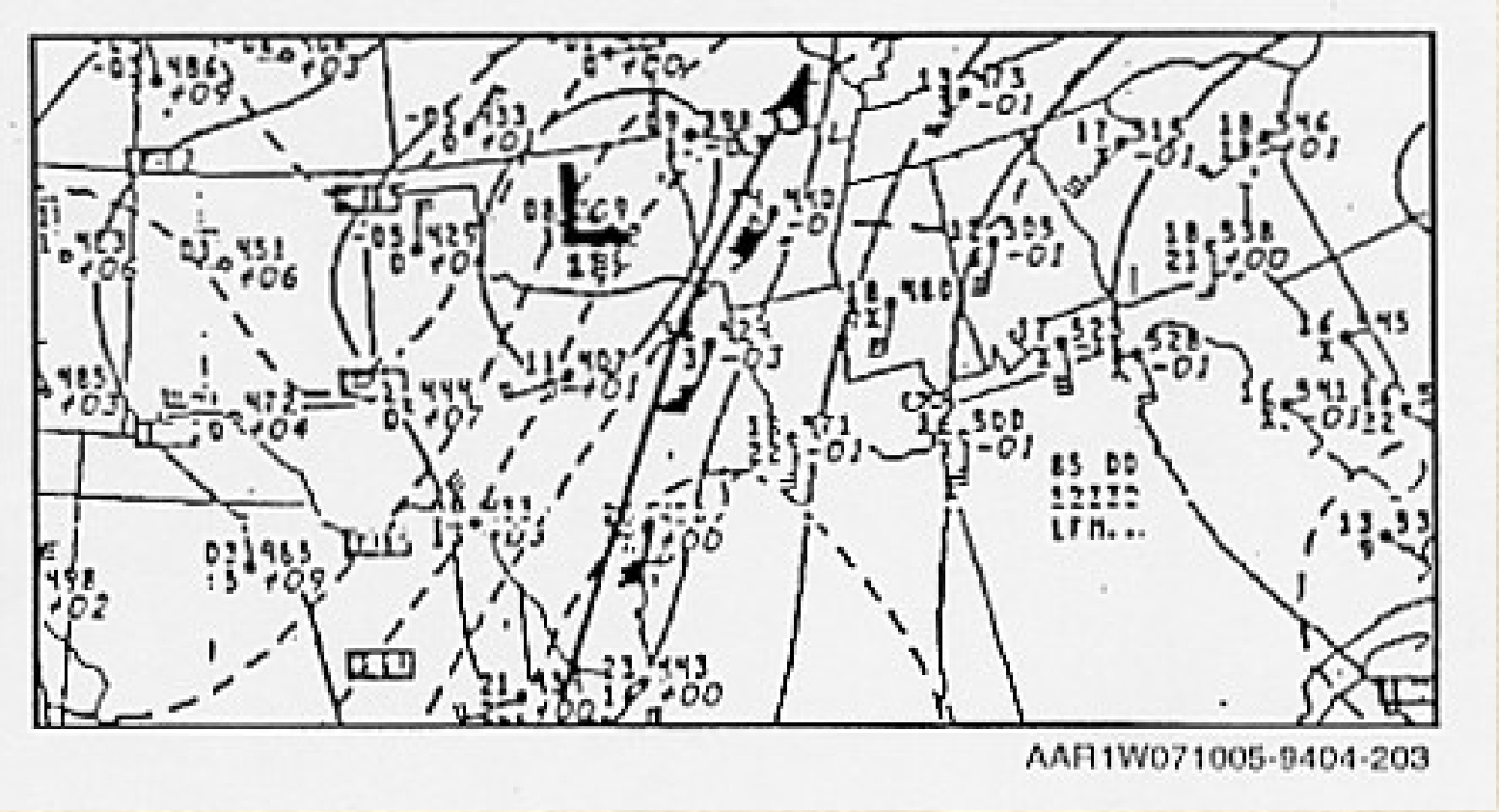
- Characteristics
  - It is a nocturnal phenomenon, which reaches its peak around sunrise
  - Daytime surface heating with vertical mixing tends to dissipate LLJ
  - It serves to transport heat/moisture rapidly northward
  - Typically forms with high over eastern US and low developing in Western Plains
  - Develops in warm sector, parallel to cold front

Low-Level Jet (LLJ)

- Favored locations in the tropics include
  - Coastal deserts with cold upwelling off-shore
    - Eastern Somalia to Eastern Madagascar
    - West Coast of South Africa
  - Areas of strong radiational cooling with channeling from inversions or mountains
    - Northeast coastal plain of Saudi Arabia
    - Northern Australia

Low-Level Jet (LLJ)

- Speeds exceeding 60 knots have been observed



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Low-Level Jet (LLJ)

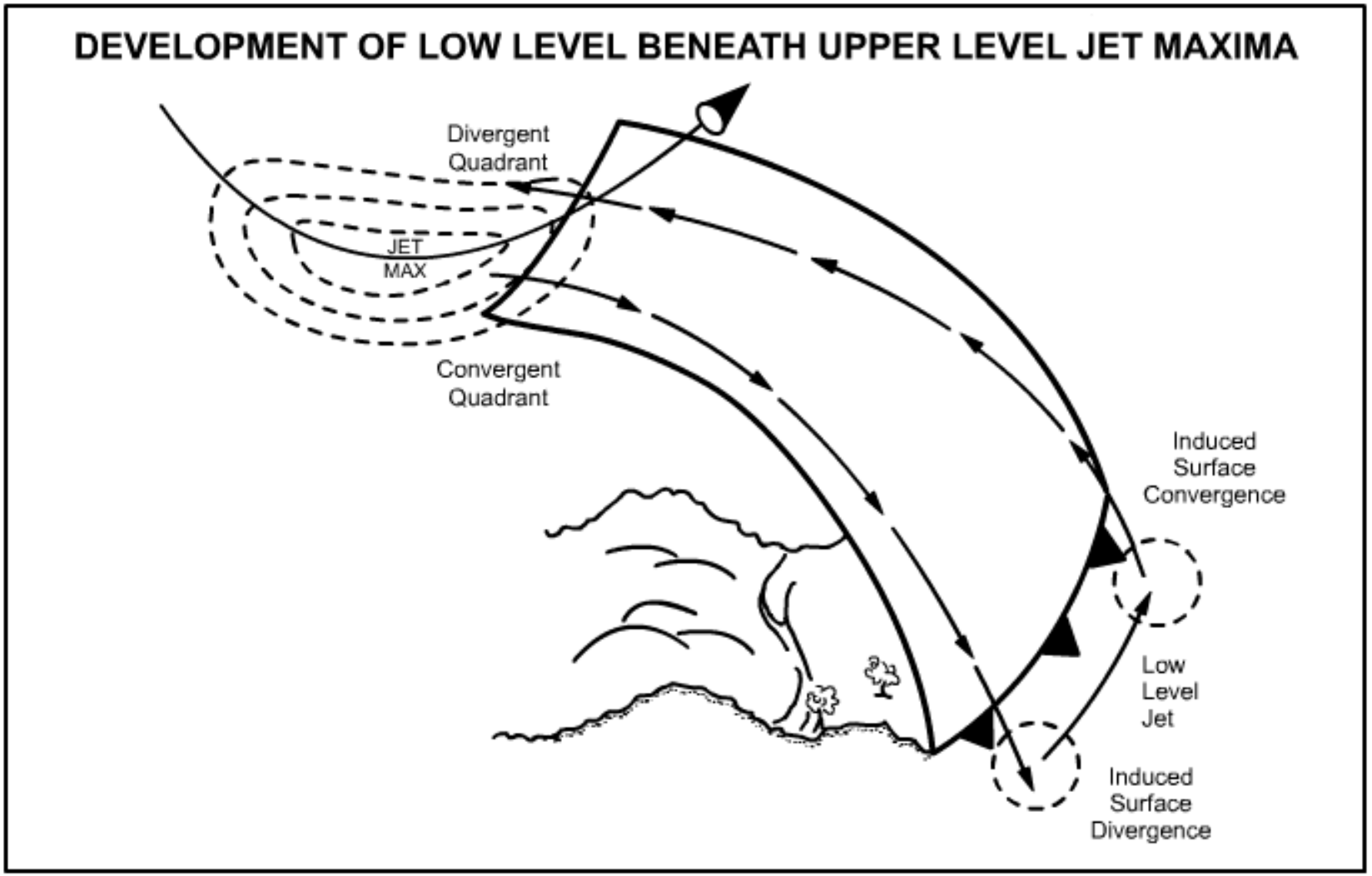
- Weather
  - Moisture and heat are transported northward and destabilizes the atmosphere which leads to thunderstorm development at nose of jet
  - If LLJ intersects warm front, intense overrunning results in thunderstorms along warm front

Low-Level Jet (LLJ)

- Causes
  - Upper-level forcing (Uccellini and Johnson, 1979)
    - Low-level jet is dynamically linked to upper-level jet stream
      - Develops beneath nose of jet max on PFJ
      - More or less perpendicular to upper-level jet axis

Low-Level Jet (LLJ)

- Cause
  - » Supergradient winds at nose deflect to right
  - » Strong divergence occurs in left front quadrant and weak convergence in right front quadrant as mass is transported from left side of jet to right
  - » Air sinks in convergent quadrant and downward vertical motion develops
  - » Low-level divergence occurs beneath the convergent quadrant of jet max


DEVELOPMENT OF LOW LEVEL BENEATH UPPER LEVEL JET MAXIMA
Divergent Quadrant
JET MAX
Convergent Quadrant
Induced Surface Convergence
Low Level Jet
Induced Surface Divergence

Low-Level Jet (LLJ)

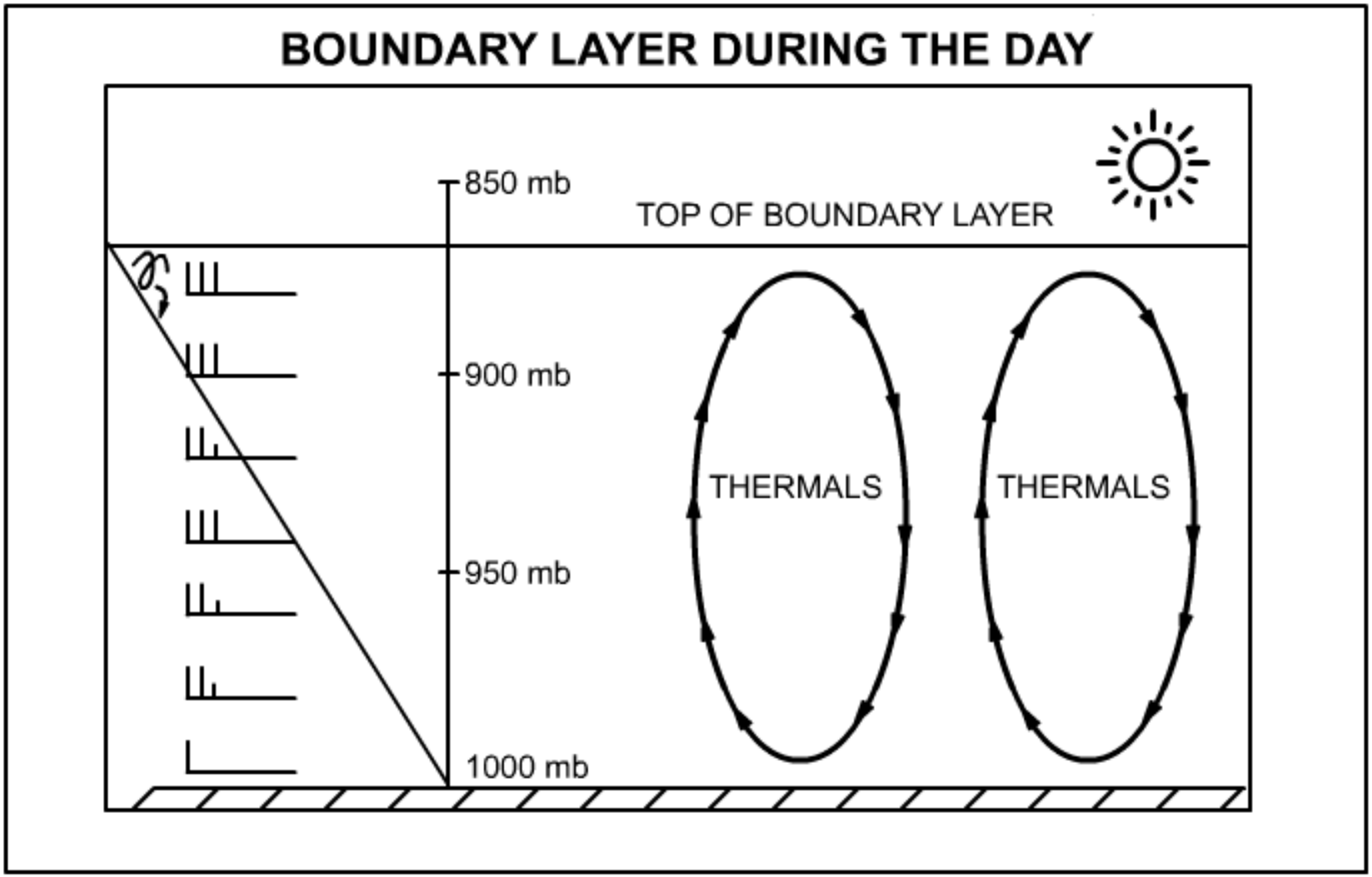
- » Air returns northward beneath upper-level jet max
- » Air flows northward to low-level convergence under divergent quadrant
- » As air rushes toward low-level convergent area, a strong southerly flow is established
- » Flow is perpendicular to jet max and completes circulation around nose of jet max

Low-Level Jet (LLJ)

- Lowering of boundary layer at night
  - During daytime, surface heating causes air in contact with earth's surface to warm
  - Lowest layer becomes absolutely unstable
    - Thermals develop due to instability and mixing occurs
    - Mixing causes boundary layer to become deeper
    - Faster moving air aloft is mixed downward and surface wind increases

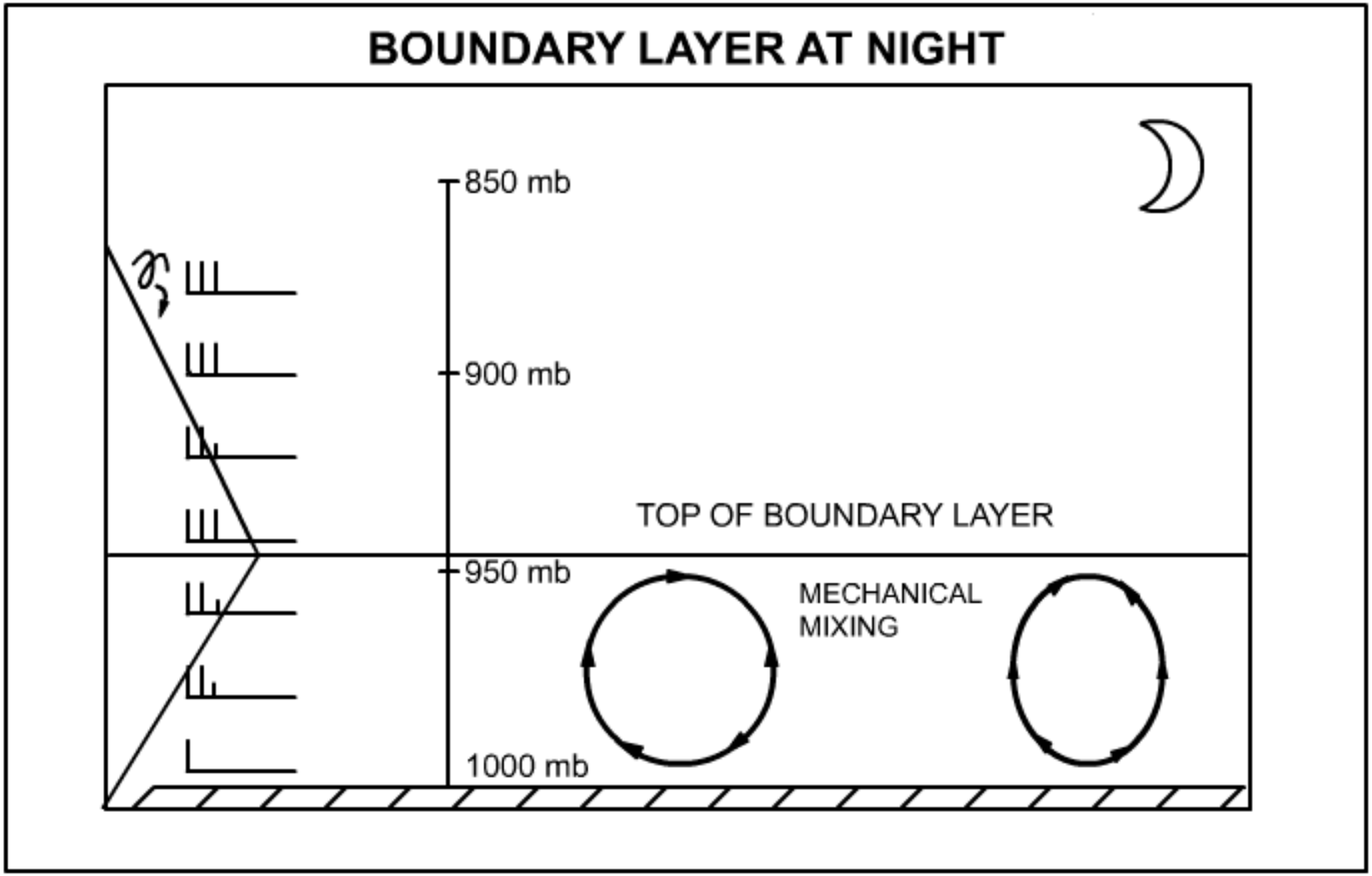
Low-Level Jet (LLJ)

- A slower moving air (due to surface friction) is mixed upward and winds speeds near top of boundary layer decrease
- Daytime boundary layer allows for air to move at a relatively uniform speed


BOUNDARY LAYER DURING THE DAY
850 mb
TOP OF BOUNDARY LAYER
900 mb
950 mb
1000 mb
THERMALS
THERMALS

Low-Level Jet (LLJ)

- After sunset, earth's surface begins to cool
  - A radiation inversion develops
  - Mixing stops and boundary layer sinks
  - Surface winds decrease
  - Slower moving air (due to surface friction) is now confined to very low levels due to inversio n
  - Even though boundary layer sinks, same amount of air must still move northward


BOUNDARY LAYER AT NIGHT
850 mb
900 mb
TOP OF BOUNDARY LAYER
950 mb
MECHANICAL
MIXING
1000 mb

Low-Level Jet (LLJ)

- Air beneath inversion is almost calm
- All the air must flow north above boundary layer
- Without lower atmosphere moving northward, wind must increase to high speeds just above boundary layer

- Both upper-level and boundary layer forcing must occur for well form LLJ

Low-Level Jet (LLJ)

- Gradient Induced Jet
  - If one condition is not met, a weak low level jet may still form
  - A LLJ may form due to gradient
    - Strong band of gradient winds will act much same way as true low-level jet
    - Weather conditions will be similar

- APPLICATION: Assign Review Exercise 5
- EVALUATION: Administer and evaluate Appraisal 205e. Give the written test at the end of the unit.